AFRL-SR-AR-TR-08-0283

REPORT DOCUMENTATION PAGE

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
27-07-2007	Final	Apr03-Dec-06

4. TITLE AND SUBTITLE
The Subpipe Project

5a. CONTRACT NUMBER

5b. GRANT NUMBER
F49620-03-1-0240

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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8. PERFORMING ORGANIZATION REPORT NUMBER
TAAAC, 26848

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AFOSR/NA 875 N Randolph St
Arlington VA
22203

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release;
distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
See attached report

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
U	U	U	UU	2	Peter Bradshaw
					19b. TELEPHONE NUMBER *(Include area code)* 650-723-2968

AFOSR grant F49620-03-1-0240
Stanford SPO TAAAC, 26848
The Subpipe Project

Final Report, July 2007

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Background

The purpose of this project was to examine the effect of surface roughness on a turbulent wall flow, in the limit of small roughness. It is, in effect, an attempt to throw light on experimental results dating from 1933, which appear to have been misinterpreted ever since as the result of an imprecise statement in the original (German) report by Nikuradse (a.k.a. Nikuradze) and its translations[1]. It was stated that below a certain Reynolds number $u_\tau k/\nu$, based on the (sand-grain) roughness height k and the friction velocity u_τ, the roughness had "no effect" on the friction factor (i.e. no effect on the additive constant in the logarithmic law for velocity). All that can be deduced from the plotted results is that the effect became smaller than the experimental scatter, and there is no reason to suppose that the roughness effect depends on instability above some "critical" Reynolds number - particularly as later estimates of this Reynolds number are very low ($u_\tau k/\nu$ in the range of about 2 to 5).

The present author[2] produced an unrigorous but plausible argument that the roughness effect should vary as $(u_\tau k/\nu)^2$ in the limit of small roughness. Briefly, the Reynolds number that matters is likely to be that based on the mean velocity at the height of the roughness (nominally $k\tau_w/\mu$ if k lies within the linear part of the viscous sublayer) and on k itself, in which case it will vary as k^2.

In order to manufacture surfaces with small roughness Reynolds number repeatably, a closed-loop pipe rig was constructed, to be run at static pressures below atmospheric (hence the name "Subpipe") to obtain low unit Reynolds numbers, so that physically-large roughness elements could be used. The practical application of the work is to the development of a more precise criterion for allowable roughness on (pressure) wind-tunnel models. Final hand polishing of a model is time-consuming and expensive, so unnecessarily fine polishing is to be avoided.

Present Position

The project has been dogged by "bad luck". Shortly after the test rig (20 ft long) was completed, the P.I. had a bicycle accident, resulting in a broken hip, severe muscle damage and restricted mobility which has persisted to some extent. This delayed the start of experimental work for over a year. Then the rig was out of action for some time because it was inaccessible behind a wind tunnel being used for an unrelated experiment which lasted much longer than expected. Finally an alternative site was found, but it was found that the rig and its motor power supply had been damaged. Repairs took a long time, and the result is that no coherent results have yet been obtained.

The project's Stanford account has been closed. I have every intention of finishing this work: my general health remains good. Further expenditure will be borne by the P.I.'s personal Discretionary Fund.

Note

In my letter of 5 Dec. 2006 (attached) I requested a further extension of the grant, in view of the unavoidable delays to the project. Our contracts office passed on an oral message that this request was denied but I have never received written notification, so there may be a gap in somebody's files.

References

1. J. Nikuradse, Laws of flow in rough pipes. VDI Forschungsheft no. 361 (1933): trans.NACA TM 1292 (1950).

2. P. Bradshaw, A note on "critical roughness height" and "transitional roughness". Phys. Fluids **12**, 1611 (2000).